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RESEARCH AND DEVELOPMENT OF THE AEROTURBINE ENGINE,(U)
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FOREIGN TECHNOLOGY DIVISION

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by

Fang Changde

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EDITED TRANSLATION

(14) FTD-ID(RS)T-1559-80 (11) 15 Apr [illegible]81

MICROFICHE NR: FTD-81-C-000337

(6) RESEARCH AND DEVELOPMENT OF THE AEROTURBINE ENGINE,

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English pages: 14

(21) Edited transl. of Source: Hang K'ung Chih Shih, Nr. 7, 1979, pp. 22-24

Country of origin: (China) nr 7 p22-24 1979,

Translated by: LI[illegible]STIC SYSTEMS, INC

[illegible]-0618

William Brown.

Requester: FTD/TQTA

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RESEARCH AND DEVELOPMENT OF THE AEROTURBINE ENGINE

by Fang Changde

The first part of this article published in the June issue of this magazine outlined the problems of preliminary research, model development and model improvements of the aeroturbine engine. Below is an introduction of the developmental process of the aeroturbine engine.

In most scientific and technological fields, development results and related scientific knowledge are used in practical technology or production activities to attain a certain product or the entire process of certain manufacturing methods and this is called development.

In the development of a new model aviation engine from the introduction of the technical demands and basic concepts to the finalization of design, testing and its approval to be put into production, it is also necessary in this process to undergo initial design, technical demonstration, work design, trial production testing, to deal with aerodynamics, engineering thermodynamics, automation technology and various data and technical disciplines, mobilize a multitude of designers, workers and other auxilliary members as well as a great deal of large scale and precision test equipment and make a capital investment of 100 million yuan over a period of four to seven years. Therefore, the developmental work for an engine is

very detailed and complex. They must draw up advanced and feasible technical demands, approximately arrange and promptly coordinate a schedule for each aspect and stage, eliminate the larger problems that occur in the development stage, undergo repeated designs, trial productions and tests and only then can they meet the needs of the engine.

The Introduction of Technical Demands and Initial Design

The most important technical demands for engines include thrust, the rate of fuel consumption, weight, measurement, reliability, life span and ability to safeguard. These demands cannot be simply attained from aircraft technical demands because these two demands condition each other and promote each other and thus must undergo repeated preliminary design and appraisal. It is necessary that this possible contradiction be resolved and only then can the engine's technical demands be finally determined.

Therefore, after the engine's technical demnds are clear, for example, the flight speed, altitude, effective load (number of passengers) and course of a civil aviation aircraft; after the flight speed, altitude, maneuverability, weapons equipment and fighting radius of a fighter plane are determined, then the aircraft's body and engine manufacturing units can research together to bring forth the prelininary technical demands for the engine.

Afterwards, a preliminary design by the engine manufacturing unit based on these preliminary technical demands can be carried out. During the preliminary design stage, it is necessary to weigh the contradictory factors of thrust, rate of fuel consumption, weight, measurement, cost, reliability

and life span based on existing technical data and the appraisal of new technical advances. During this stage, it is necessary to carry out work in the following several areas.

1. Select an engine design plan and draw up a general diagram. In the selection of a design plan there are generally several thrust points and flight lines determined according to aircraft technical demands and then the engine performance features and the engine model most able to fulfill the demands are determined. For example, whether the selection of a turbojet or turbofan carries increased power. Afterwards, the engine cycle parameters (such as the pressurized ratio of the gas compressor and the turbine intake temperature), the air runoff and thrust level are initially fixed, after calculating the heating power the air current passage is determined, the forms of each component and system are selected and a general diagram is drawn up.

2. The selection of new technology and the formulation of test plans for new technology.

Based on the achievements in the latest research and the engine's preliminary technical demands, we select and prepare new technology to be used for the engine. When selecting, it is necessary to pay attention to technical advancement and the certainty of success. If we are too conservative, this can cause the performance of the engine to be backwards and if we advance rashly, this can effect the rate of development and even cause failure in the whole engine and even the whole aircraft. This is an extreme lesson in the history of engine development. If a certain nation was still not mature during the 1940's in the development of axial-flow gas compressors

and was impatient in employing bombers with engines which used relatively advanced axial-flow gas compressors so that before testing the engine in the whole aircraft they did not test all the parts the results would be that the platform test of the engine would not last two hours. Therefore, later they must again research the axial-flow gas compressor which will effect the speed of the development of the whole engine and aircraft.

After selecting new technology, a test plan must be formulated. The carrying out of many tests of each component and system using the new technology will cause it to reach the required level and guarantee a solid foundation for the testing of the engine. If when a certain nation is developing a high flow ratio turbine fan, before testing the whole engine, several thousand hours of tests should be carried out on one hundred and sixty-one components.

3. Suggesting matching demands for the engine and aircraft.

The problem of matching the engine and aircraft has already become one of the major difficult problems in developing modern fighters. During the intial period of development, it is necessary to resolve this problem.

Based on the preliminary design general diagrams and selected new technology, a wooden prototype can be built to test the components and test and verify the aircraft tests. Afterards, the preliminary design plan and wooden prototype are given to the aircraft manufacturing unit so that they can make a preliminary design and appraise the aircraft. At the same time, they can verify and test the selection and use the new technology.

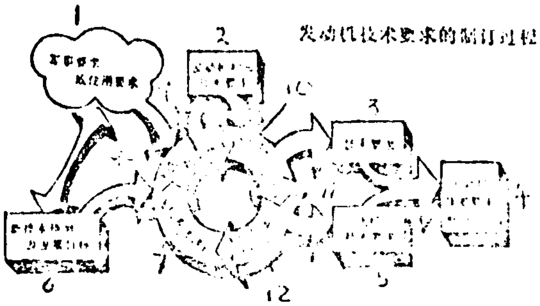


Chart 1 The Process of Formulating Engine Technical Demands

1. Military or service demands
2. Engine preliminary technical demands
3. Technical demands
4. The last formulation of engine technical demands
5. Aircraft technical demands
6. Calculation of new technology and development goals
7. Aircraft system research
8. Aircraft
9. Preliminary demands
10. Engine
11. Preliminary design
12. Preliminary design and appraisal of aircraft

Technical Proof and Selection Through Appraisal

After making preliminary designs and appraisals of the finished aircraft, the aircraft's technical demands are obtained. At the same time, the engine's new technology also undergoes test verification which can prove the technology. Technical proof includes the following:

To prove that the final determined technical demands are advanced and reliable;

To prove that the engine plan being used can satisfy technical demands;

To prove that the new technology being used is sufficiently controlled;

To show that the best methods are used for resolving technical problems;

To prove that the cost and time needed for development are feasible,

If there are more than two units participating in the preliminary design and technical verification, then after comparing research they can select the best engine plan from among them.

方案论证讨论会

Chart 2 Plan Proof Discussion Meeting

Work Design

After technically proving and formulating detailed technical demands for the engine, on the foundation of the preliminary design plan, the manufacturing unit can begin to carry out a work design for the prototype so that the whole plan can be concretized. It can be said that this is

placing the meat down on the frame of the technical plan and careful arrangements must be made for each structural component of the engine. For example, the gas compressor and turbine blade and clearance of their shared casing should be as small as possible so as to decrease gas loss. For this, the casing must be symmetrical and always maintain a circular form. In the engine work process, under the actions of centrifugal force, temperature and pressure, the expansion or contraction of the casing, disc and blade must be as uniform as possible, otherwise, if the clearance increase does not cause the aerodynamic efficiency to decrease then the blade tip and casing will "get stuck" and even cause the blade to break and result in a mishap. In design, it is also necessary to consider the engine's operability, its safeguarding must be good, its ability to resist outside substances (such as birds, sand etc.) must be strong and it is also necessary to have safety protection measures so as to guarantee that when there is one or several breakdowns this cannot be critical to the safety of the whole aircraft.

After completing the structural design, it is necessary to draw up detailed assembly diagrams for each component for the convenience of building and assembly by the trial-manufacture department. Each detailed diagram must be carefully drawn to symbolize the geometric shapes, measurements, materials, processing methods and heat control conditions. Decided tolerance in diagrams is one of the most complex problems in engine design. Tolerance not only reflects the technical demands but also shows the ability of the manufacturing department.

During the entire design process, it is necessary to seriously consider

weight. Because the total weight of the engine is seriously set in the technical demands, all of the designers must fix the weight of each component according to past experiences and the concrete design of parts and afterwards they must be distributed to the components. The weight is decreased by "grams" for certain components.

At the same time, the design department must be closely linked to the trial-manufacture department in formulating a detailed design. Moreover, as early as possible they should inform the trial-manufacture department as to the needed number of processed components, the general measurements and the technical demands of the various semifinished products especially the demands of key components which are hard to process. In this way, they can do well production preparations and guarantee that the first prototype be completed on schedule.

Trial-Manufacture of the Prototype

The so-called prototype indicates the first full sized engine used for the testing of a new technology engine. After test operations, the existing problems in design are gradually exposed and resolved so that the engine reaches the stipulated technical demands. In order to shorten the time for development, the fast processing of a sufficient number of prototypes and altered parts is very important.

The Allocation and Scale of the Power of Trial-Manufacture

The special features of trial-manufacture are that the batch is small, changes are great and in the development process the same components can be revised. Because of this, it is necessary that trial-manufacture work be in

a large batch as it is relatively difficult for it to go to an assembly line. At present, in many nations which are able to independently develop aviation engines, all of the engine manufacturing companies or design bureaus have specialized trial-manufacture departments whose scale is relatively small and whose annual output is about 20 to 30 engines. In order to adapt to the small batch and great changes of trial-manufacture prototypes all trial-manufacture factories are equipped with technically trained workers and homogeneous shops.

The Number of Prototypes

In the past, when developing a new model engine, the manufacture of 8 to 12 prototypes was sufficient for testing. At present, the technical level of engines has become more complex and the number of prototypes needed has increased. As regards civil aviation engines, the civil aviation bureaus of many nations fix the number of prototypes at no less tham 20. Based on statistics, the average is 30. Yet, there are great differences depending on the situation of the nation and the level of technical complexity. For example, in the engine used in the first supersonic civil aircraft, more than 16 prototypes were used in development.

Among these prototypes, there were generally 6 to 8 used in ground tests and the remianing were used in flight tests. For example, a certain model engine prototype had the following tests on the ground.

Performance tests	2 engines
Reliability time tests	1 engine
Safety tests	1 engine
Environment and noise tests	2 engines
Controlability and systems tests	1 engine

In manufacturing prototypes the following problems should be given

attention to:

1. There must be a large number of semifinished components remaining so that after small revisions are made on the components the original semi-finished components can still be used.

2. It is necessary to use precise and complex technical equipment to be able to make complex components. Because of this, it is necessary to design and build the technical equipment quickly and be able to mass produce it so that after the design is fixed it can be mass produced quickly.

3. Sometimes it is important that some of the prototypes when made in a trial-manufacture factory be produced in mass. Generally speaking, when the number of components built in a trial-manufacture factory is small, most of the components (such as blades) and the forged and cast large scale semi-finished components (such as the semifinished cast casing and semifinished forged disc) can be built in a production factory.

Testing of the Prototypes

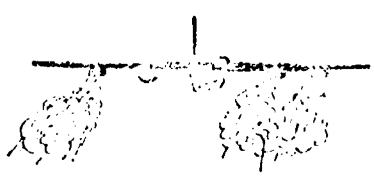
The testing of the prototypes is very important. Because the work process of the engine is very complex, reliance on a single past experience and theoretical analysis cannot be used for design to completely accord with the actual situation. Only if there is testing in the actual conditions and continual revision of errors in design can the design demands be met beforehand. Moreover, there is mutual interference among the various parts of the engine and therefore parts' tests cannot substitute for tests of the whole engine.

Prototype tests can be divided into two stages.

From the First Test to the Qualification Test Before Flight

The costs of tests on the whole engine are very high. When an engine with a thrust of ten thousand kilograms is driven for one hour its fuel consumption is 5 to 6 tons. Because of this, whenever possible components tests are carried out. Generally, it is necessary to wait until after the performances of major components are fundamentally qualified to begin the first test.

Before flight, qualification tests verify the performance and flight safety of the engine under fixed conditions which generally last 50 to 60 hours. After this, the engine can be installed in a trial run block for test flight. This type of trial run block can be made from existing large scale reequiped aircraft, the engine can be tested when fitted on the aircraft and flight tested when put in the air. In order to guarantee flight safety, most important is for the aerial trial run block to depend on the originally installed engine for power. Sometimes it can also depend on a tested engine for power (see chart below).



JT9D [illegible]

Chart 3 Front View of the JT9D Engine (Middle Left) in Aerial Trial Run Flight Test

For a relatively experienced unit, it is not difficult to attain the design performance index (most important are the thrust and fuel consumption rate) of a new technology engine in a ground rig test. Yet, when we want to attain the flight performance under fixed conditions especially the special features of flame-out and reignition, this is not that easy. Common ground rig tests cannot test flight performance and before being installed in an aircraft for flight tests it is necessary to first install the engine in high altitude simulated test equipment to simulate a flight conditions test.

From the Qualifications Test Before Flight to the Testing of the Final Design.

During this stage, besides carrying out a large number of ground tests, it is also necessary to carry out extensive flight tests of the engine installed on an aerial flight block or a completely developed new aircraft prototype. An important task is to perform a few improvements in performance, to raise the reliability and life span to a level for production, to investigate the matching performance of the engine and aircraft and determine the protective performances of breakdown analysis and the exclusion of breakdowns technique. After the design index is attained from a large number of ground and flight tests, it can be given to the nation for fixed model tests.

Fixed model tests are examined and approved by the nation's specialized aviation products appraisal organization and engines used by the military are examined and approved by the military. The essential goals of fixed model tests are:

1. To appraise whether or not the engine's performance parameters correspond to technical demands;

2. To investigate the life span and reliability of the engine;

3. To investigate the basic performance parameter stability of an engine during a fixed life span;

4. To determine a standard for production of the engine.

Concrete test plans must be formulated by the appraising organization and manufacturing units based on the engine's technical demands and development situation. It is generally necessary to carry out long term testing of one to several times continuously for 100 to 150 hours and among these tests there is the high altitude simulated test under fixed flight conditions. After these tests, the engine gets a certificate of quality and can then be put into production.

Conclusion

The emergence of a new model aviation turbine engine is the achievement of the collective labors of a multitude of people under unified organizational leadership. Each organization and individual engaged in aviation turbine engine research and development resemble each part and component of a tremendous and complex machine and each is different and essential. However, in order for each of the organizations and individuals to work as a unified whole it is necessary that there be meticulous and effective organizational administration and that each organization and individual be able to be brought into full play by formulating programs, rationally dividing work among each research problem and having advanced cooperation in each area as well as logistical safeguards. The history of modern science and technology has already proven that organizational administration work determines the speed

of the development of science and technology and is the key to its success and failure. Therefore, it is called the science of science.

In the area of aviation turbine engine organizational administration, it is necessary to study the patterns for the study and development of aviation engines, to absorb the lessons of domestic and foreign successes and failures so that the direction of present and future research and development will be clear, there will be organizational cooperation and even greater achievements.